REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 3 Period--Jan. 1 to Mar. 31, 1942

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Corn Storage

Effect of Temperature on Insect Abundance*

As previously reported thermocouples were installed in 130 bins of corn scattered over the Commercial Corn Area, and temperature readings are being taken once a month. In addition, quarterly samples of grain are being taken for the determination of grade, germination, fat acidity and insect infestations. The location of the bins under observation are as follows:

Illinois--Champaign, Iroquois, Henderson, La Salle, Sangamon, and Whiteside Counties
Iowa--Cerro Gordo, Henry, Montgomery and Osceola Counties
Minnesota--Nicollet and Yellow Medicine Counties
Nebraska--Antelope and Richardson Counties
S. Dakota--Roberts and Minnehaha Counties

Temperature observations made during the period October, 1941, to March, 1942, show that there has been a gradual drop in bin temperatures during the winter months and in most bins this has amounted to 30° F. or more. These differences are shown in table 1 and reveal that in the more northerly locations bin temperatures have averaged lower than those in the southern parts of the region.

Samples from all of the bins except those in Illinois were taken in October, 1941, and all of the bins were sampled in March, 1942. The results indicate that there has been no material change in grade in the corn stored in the bins, although in some cases there has been an increase in moisture content on the surface. However, this excess moisture in the surface layer has not affected the general condition of the grain.

* Reported by H. H. Walkden and J. M. Magner, in cooperation with the Bureau of Agricultural Chemistry and Engineering and State Entomology Departments of Illinois, Iowa, Nebraska, Minnesota, and South Dakota.

Table 1: -- Average temperature of stored corn in the center of steel bins in the Commercial Corn Area, October, 1941, and March, 1942.

Locality	No. bins	Mean Temperature October, 1941 Degrees F.	Mean Temperature March, 1942 Degrees F.
Sesseton, Roberts County, S. Dak.	3	62	30
Hartford, Minnehaha County, S. Dak.	3	64	37
Clarkfield, Yellow Medicine County, Minn.	10	66	32
St. Peter, Nicollet County, Minn.	8	66	33
Clearwater, Antelope County, Nebraska	12	68	38
Verdon, Richardson County, Nebraska	7	74	39
Ashton, Osceola County, Iowa	12	64	34
Rockwell, Cerro Gordo County, Iowa	6	67	36
Red Oak, Montgomery County, Iowa	11	69	39
New London and Olds, Henry County, Iowa	10	82*	43
Prophetstown, Whiteside County, Ill.	8	No record	39
Missel and Triumph, La Salle County, Illinois	8	No record	38
Biggsville, Henderson County, Ill.	8	No record	41
Claytonville and Buckley, Iroquois County, Ill.	8	No record	42
Lanesville, Sangamon County, Ill.	8	No record	42
Tomlinson and Thomasboro, Champaign County, Ill.	8	No record	No record
	130		

* Heavy insect infestation in 2 bins caused abnormal rise in temperatures.

A comparison of the insect populations existing in the bins in October, 1941, with those present in March, 1942, shows that, in general, insect populations have been greatly reduced during the winter months. The relative abundance of the various species is given in table 2, together with the winter survival for the Commercial Corn region as a whole. It will be seen that, with the exception of the Indian meal moth and *Typhaea stercorea*, 90 percent or more of the insects found in October, 1941, were living, whereas by March, 1942, only 3 species, namely, the sawtoothed grain beetle, the flat grain beetle, and *Cynaeus angustus* show a survival of 25 percent or more.

Winter mortality north of the latitude of Des Moines, Iowa tended to be greater than in the area south of that point. The localities have been placed in two groups, as indicated in table 3, It will be seen that by far the largest numbers of insects occur in the southern portion of the area, and that the greatest winter mortality occurs in the northern region.

Table 2: -- Relative abundance and winter survival of species of insects found in corn stored in steel bins in the Commercial Corn Area, October, 1941, and March, 1942.

Species	October, 1941		March, 1942		October 1941	March 1942
	Living	Dead	Living	Dead	Living	Living
	Number	Number	Number	Number	Percent	Percent
Flat grain beetle	358	24	551	410	93.7	57.3
Cynaeus angustus	45	2	73	203	95.7	26.1
Sawtooth grain beetle	1031	139	438	814	88.1	53.9
Rust-red flour beetle	294	11	481	3468	96.4	12.2
Indian meal moth	26	93	1*	288	21.8	0.3
Foreign grain beetle	121	24	5	1366	83.4	0.4
Typhaea stercorea	64	61	0	90	51.2	0
Granary weevil	1	0	1	13	--	-
Rice weevil	14	1	11	4	--	-
Cadelle	1	1	5	5	--	-
2-banded fungus beetle	0	0	0	1	--	-
Yellow meal worm	0	3	0	1	--	-
Platydema ruficornis	0	0	0	12	--	-
Dermestids	7	1	16	12	--	-
Spider beetles	2	0	1	3	--	-
Totals	1964	360	1583	6690	84.5	19.1

* 1 living larva found in sample from Rockwell, Iowa.

Table 3: -- Comparison of the relative abundance and winter survival of the more abundant corn infesting species of insects in the northern and southern sections of the commercial corn area, March, 1942.

Species	Northern Section*			Southern Section**		
	Living	Dead	Living	Living	Dead	Living
	Number	Number	Percent	Number	Number	Percent
Flat grain beetle	28	34	45.2	523	376	58.1
Cynaeus angustus	13	34	27.7	60	169	26.2
Sawtooth grain beetle	2	4	33.3	434	812	34.8
Rust-red flour beetle	6	203	2.9	466	3365	12.2
Indian meal moth	1	121	0.8	0	167	0
Foreign grain beetle	1	179	0.6	4	1187	0.3
Totals	51	575	8.2	1487	6076	19.7

* The northern section includes: Roberts and Minnehaha Counties, South Dakota; Antelope County, Nebraska; Yellow Medicine and Nicollet Counties, Minnesota; Osceola and Cerro Gordo Counties, Iowa.

** The southern section includes: Richardson County, Nebraska; Montgomery and Henry Counties, Iowa; Whiteside, Henderson, La Salle, Sangamon, Iroquois and Champaign Counties, Illinois.

Turning and cleaning

The cost of turning and cleaning corn stored in steel bins has been found to vary from ½ to 1 cent per bushel, depending on the type of equipment used and the arrangement of the bins.

In McLean County, Illinois, a total of 2,000,000 bushels of corn have been turned during the past year. The equipment consisted of two elevators and a 24-foot 6-mesh gravity screen. The cost amounted to 0.86 cents per bushel.

Wheat Storage

Condition of wheat in steel bins at Experimental Storage Sites*

During January and February samples of wheat were taken from all bins at the experimental storage sites at Hutchinson, Kansas and Jamestown, N. Dakota. As a check on the insect population of this wheat, samples of from 3-5 quarts of wheat from each bin were examined for insect infestation. The results of this examination reveal that there has been a marked decrease in infestation in the wheat stored at Jamestown, since the November, 1941, sampling, and a sharp increase in the infestation at Hutchinson, Kansas during the same period. At Jamestown, the November sampling showed that 19 percent of the bins were infested whereas in the February samples only 7 percent were infested, a drop of 12 percent. Only a single bin, one of those in the series designated for turning in cold weather, graded "weevily". After turning, subsequent samples from this bin showed some infestation but not enough to grade weevily. Thus it is apparent that the insect infestation in the wheat stored at Jamestown is practically negligible. At Hutchinson, however, the situation is quite the reverse. In October, 40 percent of the bins were infested, 9 percent of them grading "weevily". The January samples showed 69 percent of the bins to be infested with 16 percent grading "weevily", an increase of 29 and 7 percent in infested and weevily bins respectively. The intensity of infestation varied from 0 to 66 insects per 1000 grams of wheat.

From these data it is apparent that winter temperatures in the latitude of Hutchinson, Kansas have had but little effect in retarding or reducing insect populations in wheat stored in steel bins, whereas at Jamestown, North Dakota, winter temperatures have further reduced the light infestation existing in November, 1941. A comparison of the infestation at the two storage sites is given in table 4.

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* Reported by H. H. Walkden and R. B. Schwitzgebel.

Table 4: -- Comparison of insect infestation in wheat stored in steel bins at Jamestown, North Dakota and Hutchinson, Kansas.

	Jamestown, N. Dakota				Hutchinson, Kans.			
	November 1941		February 1942		October 1941		January 1942	
	Bins infested Percent	Bushels infested Number	Bins infested Percent	Bu. infested Number	Bins infested Percent	Bushels infested Number	Bins infested Percent	Bu. infested Number
"Weevily" bins	1	2,700	1	2,700	9	31,000	16	41,000
Infested, but not weevily	18	40,000	6	16,000	31	74,000	53	137,000
Total infested	19	42,700	7	18,700	40	105,000	69	178,000
Total No. of bins sampled	139		133		144		135	

Ten species of living stored grain insects were found in the January sampling at Hutchinson, whereas only one species was found at Jamestown. These species, together with their relative abundance, are listed in table 5. It will be seen that at Jamestown the flat grain beetle is the only species surviving the winter to date, whereas the rust-red flour beetle, the flat grain beetle, the lesser grain borer, and the rice weevil have persisted in considerable numbers in the Hutchinson bins.

Table 5: -- Relative abundance of the various species of insects found in the bins at Jamestown and Hutchinson, January and February quarterly sampling.

Species	Jamestown, N. Dakota	Hutchinson, Kans.
Rice weevil	0	51
Granary weevil	0	2
Lesser grain borer	0	67
Flat grain beetle	23	407
Rust-red flour beetle	0	771
Sawtooth grain beetle	0	3
Foreign grain beetle	0	2
Cadelle	0	3
Long-headed flour beetle	0	2
Undetermined larvae	0	6
Total number of living insects	23	1314

Tests for grade, fat acidity, and protein made by the Agricultural Marketing Service indicate that there has been no change in wheat quality since October-November, 1941, sampling insofar as numerical grade is concerned. However, at Hutchinson, the average fat acidity for all wheat has increased from a level of 23 to 24 units. This change in the average level has been due mainly to an increase of from 4 to 6 units in 15 of the bins, in 10 of which the insect population has increased markedly since October, 1941. Further observations will be made to determine the relation, if any, between insect infestation and the fat acidity of the wheat. It is thought that the higher temperatures existing in the more heavily infested bins may be the principal cause of the increase in fat acidity.

A careful study of the data obtained from the several experimental groups of bins has failed to reveal any marked differences in insect infestation which may be attributed to type of bin construction or management practice, with the exception that grain in bins equipped with perforated L-tube ventilation showed the least infestation at the time of the January sampling. Such bins have averaged 3° F. cooler than plain bins during the winter months, the greatest differences being noted in the grain in the center of the bins. Wheat in bins receiving no treatment since filling in July, 1941, were the most heavily infested at the Hutchinson site, a condition which was expected in the light of past experience.

Turning of wheat in cold weather

A series of 10 bins at Hutchinson and 8 bins at Jamestown have been designated to test the practicability of prolonging the safe storage period by the regular turning of the grain once each year in cold weather. At Hutchinson the series consists of three plain 2740-bushel bins, one plain 4000-bushel bin, one 2740-bushel bin equipped with a solid L-tube, one 2740-bushel bin with a perforated L-tube, and two plain 1000-bushel bins, all filled with hard red winter wheat. At Jamestown the series comprises three plain 2740-bushel bins and 2 plain 1000-bushel bins of spring wheat, and three plain 2740-bushel bins of Durum.

All of the wheat in these 18 bins was turned during January. The transfer of the grain from one bin to another was accomplished by means of a John Deere tubular elevator equipped with a Thiemann grain remover. The rate of turning averaged approximately 500 bushels per hour. Tests showed that approximately 15 seconds were required for the passage of the grain through the elevator, thus exposing the grain for only a very short time. Nevertheless, the turning resulted in a breaking up of the high moisture areas, the re-distribution of the insect populations, and the lowering of the temperature in the bin centers, as shown by observations made before and after turning. In most cases, temperature at the bin center was reduced 20° F.

After the bins were emptied, they were inspected to determine the amount of spoilage. Only small amounts of out-of-condition wheat were noted, the largest amount observed aggregating about 3 quarts in one of the bins, and for the most part the spoilage occurred at the junction of the floor and wall.

A total of 41,000 bushels was turned at a cost of approximately 1/4 cent per bushel.

Floor investigations

A total of 52 1000-bushel bins, 26 at Hutchinson and a like number at Jamestown, are under observation to test the efficiency of 13 different types of floor construction. Included are steel floors over four kinds of fills, seven concrete floors over various kinds of fills or other treatments, and single and double board wood floors. During January, samples for moisture and insect data were taken with a grain probe from each bin, the three bottom cells being kept separate so that the moisture and insect gradients could be determined. The results at both Jamestown and Hutchinson were substantially the same: (1) there was a slightly higher moisture content in the wheat near the floor, regardless of floor type, than in wheat taken one foot above the floor; (2) this difference was more marked in bins having concrete or wooden floors than in those having steel floors; (3) insect infestations were very light in all of the bins, and no differences between floor types could be detected.

Insect and moisture traverses

Under the present method of sampling, the insect infestation is determined from a composite sample. By this method the individual probe samples, 10 in number, are merged, making it impossible to determine in which part of the bin the insects are concentrated. In order to discover the location of the infestation in bins of various sizes and types it was decided to re-sample a series of bins which graded "weevily" on the basis of the January average samples. For this purpose 9 plain 1000-bushel bins, 6 plain 2740-bushel bins and 2 2740-bushel bins equipped with L-tubes were chosen, and samples were taken in the positions indicated in figure 1.

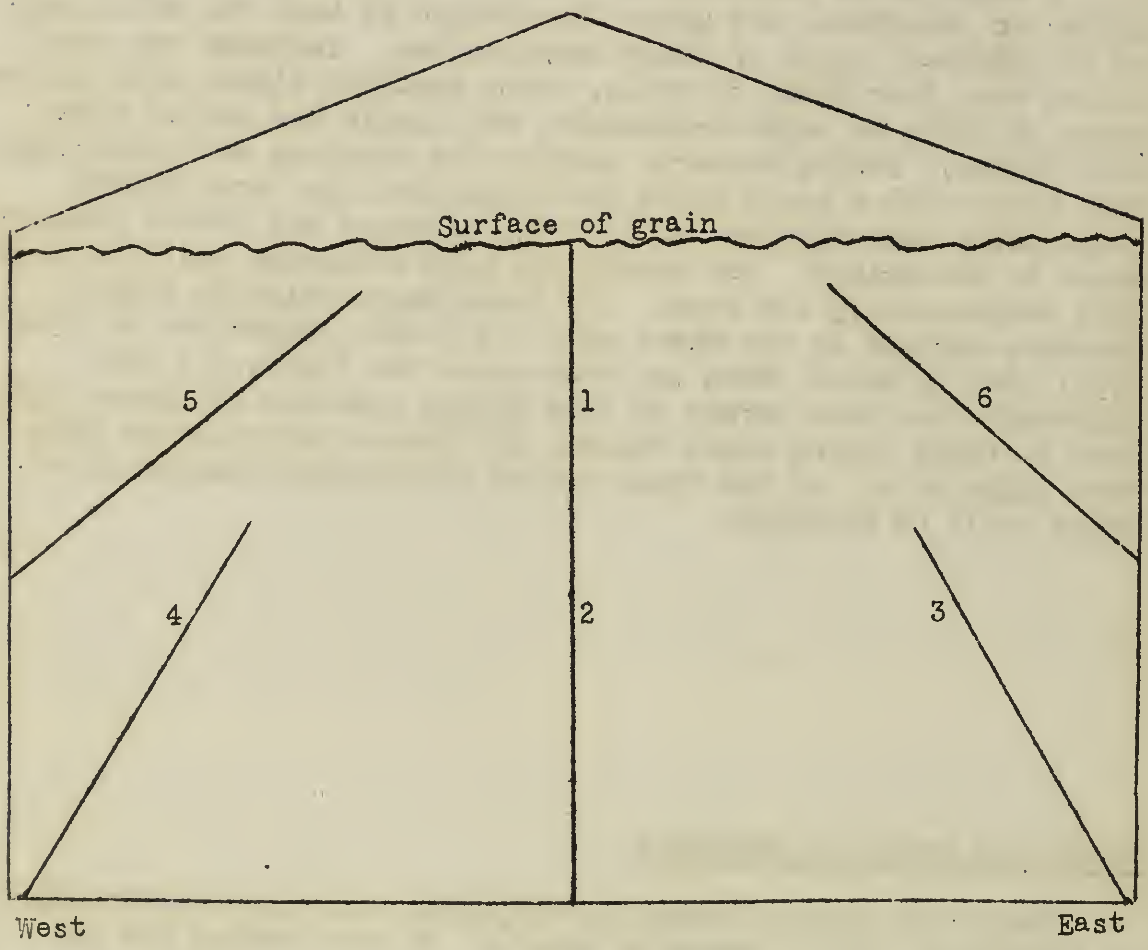


Fig. 1:--Diagram showing the location from which probe samples were taken in making insect-moisture traverses of bins.

Note: Positions 7 and 8 on the north side correspond to 4 and 5, while positions 9 and 10 are on the south side in the same location.

There are 13 feet of wheat in 2740-bushel bins, and 8 feet in 1000-bushel bins.

The grain from each of the probe cells was examined for insects and the moisture content determined. In this manner the location of centers of infestation and high moisture were revealed. From the data thus obtained, the winter pattern of infestation at Hutchinson appears as follows:

1. With one exception, the infestation in plain 2740-bushel bins was located in the upper center portion of the grain from 1 to 6 feet below the surface (figure 2). In the case of the one departure from this condition, the infestation was centered midway between the south wall and the center of the bin (figure 3).

2. In bins equipped with L-tube ventilation the insects were concentrated near the south wall (figure 4).

3. In 1000-bushel bins the centers of infestation were located either in the center of the bin (in 5 cases), or near the south wall (in 4 cases).

With regard to the moisture content of the grain in the centers of infestation, moisture traverses showed that it was no higher than in uninfested parts of the bin, but the surface foot of grain over such centers contained 2 to 6 percent more moisture than grain from lower levels. In one bin sufficient moisture had accumulated to cause molding and crusting on the surface with the resultant loss of about 12 bushels of grain in the top foot. This is the first instance in which surface crusting has occurred in wheat stored in steel bins, although this is a common condition in infested corn bins. The moisture, insect and temperature profiles obtained by traverses in the above bin are shown in figure 5 A and B.

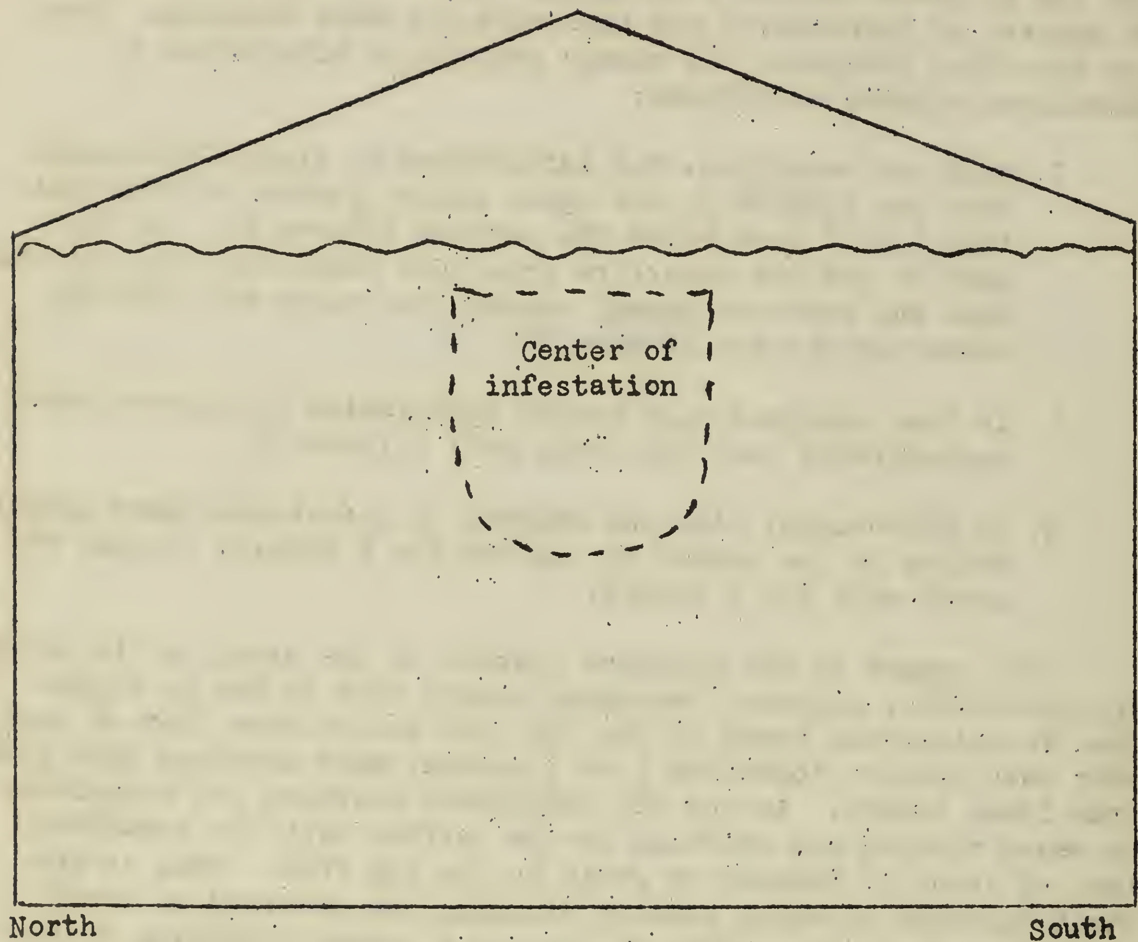


Fig. 2:--Diagram showing most common winter pattern of infestation in 2740-bushel bins at Hutchinson, Kansas.

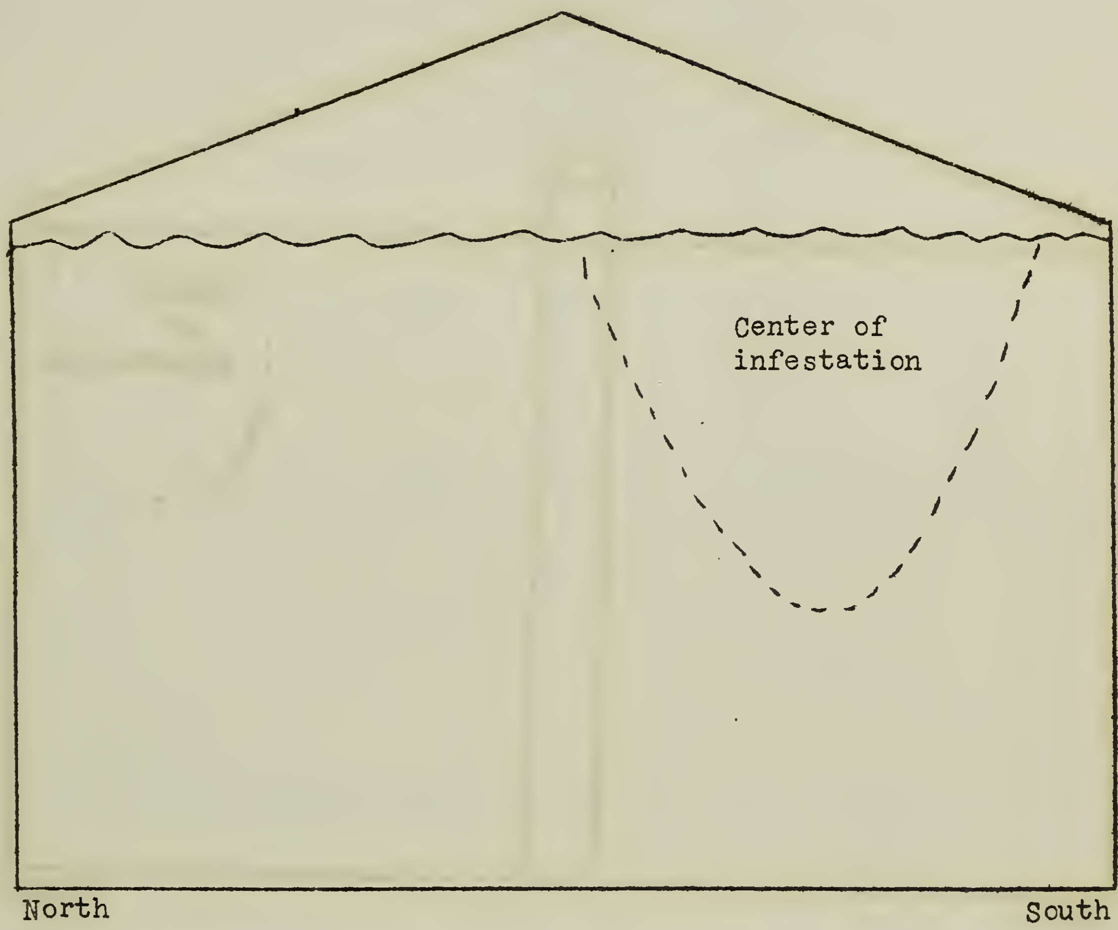


Fig. 3:--Diagram showing center of infestation in south portion of bin, Hutchinson, Kansas. This type of infestation was more frequently encountered in 1000-bushel bins.

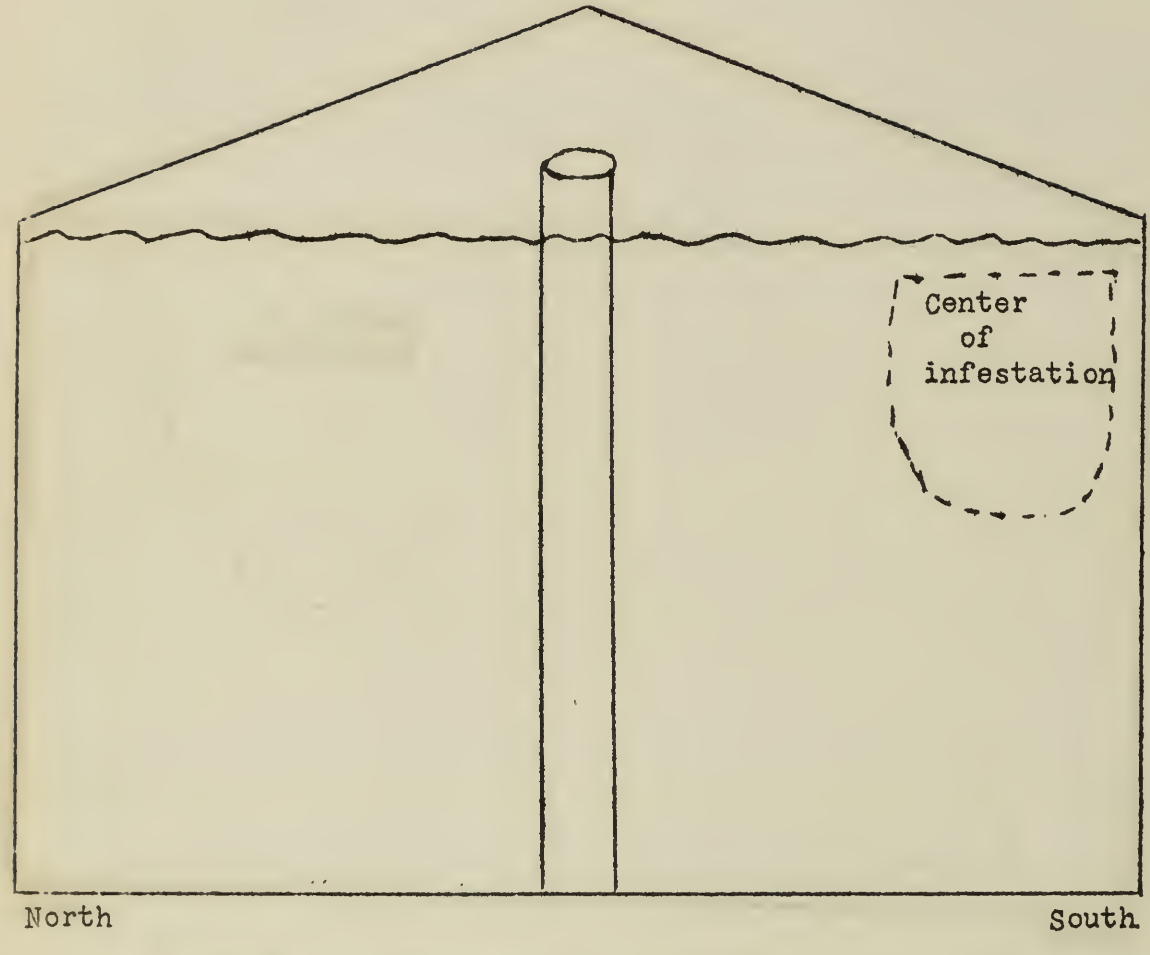
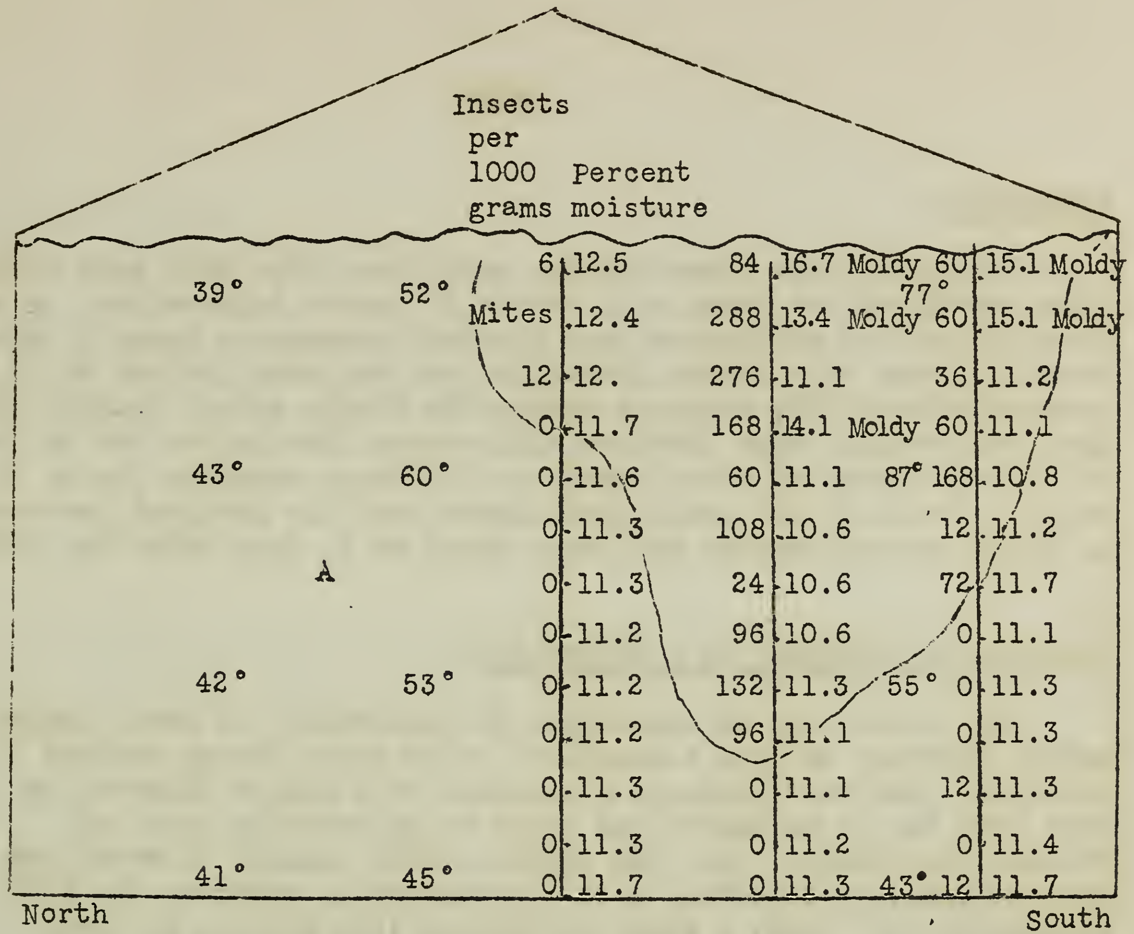


Fig. 4:--Diagram showing winter pattern of infestation in bins equipped with L-tube ventilation.



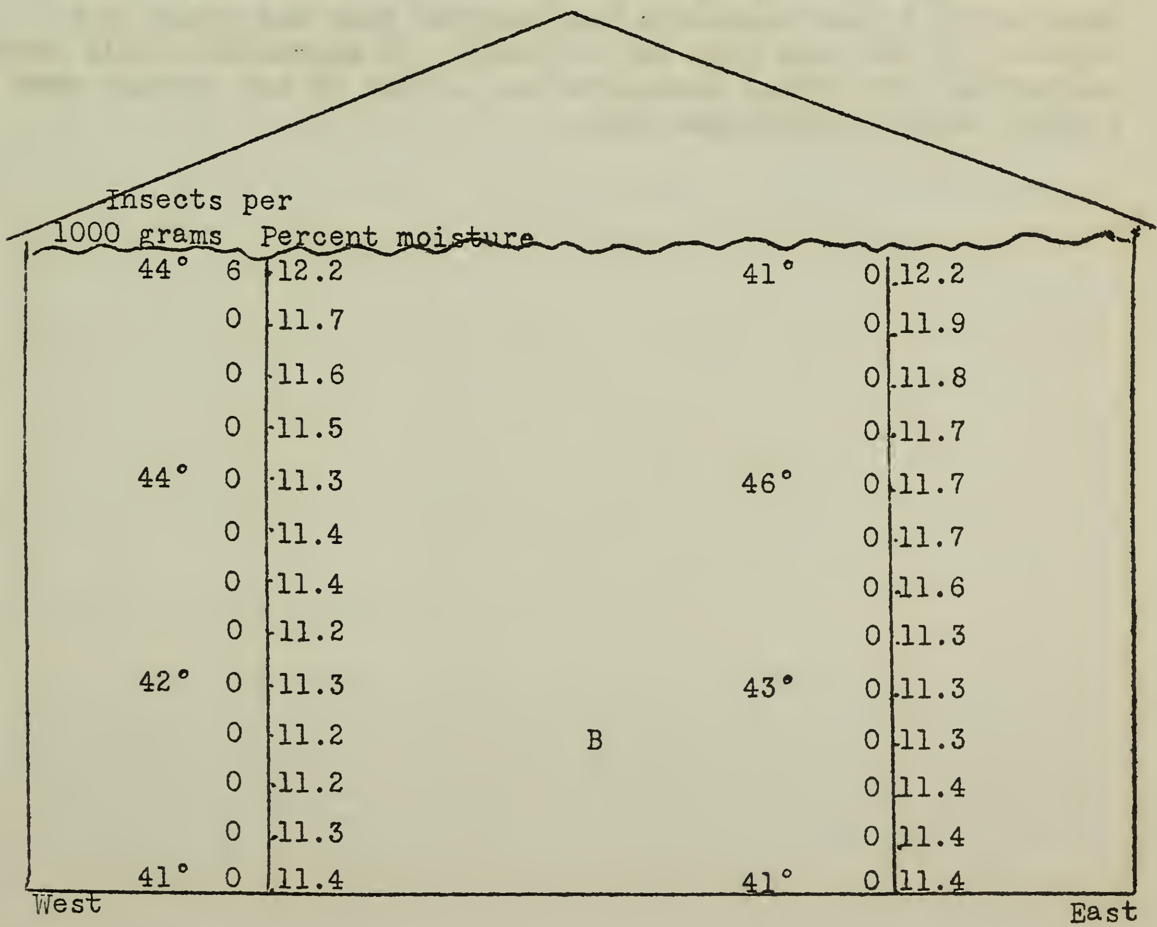


Fig. 5:--Diagram of insect-moisture-temperature traverse of heavily infested bin at Hutchinson, Kansas, March, 1942.

Fumigation

During the last three months, only those bins have been fumigated which developed hot spots as a result of insect infestation. A total of eight bins at Hutchinson have required treatment, seven of which were fumigated with carbon disulphide and one with Dowfume Br 10 (Carbon tetrachloride 22.5%, ethylene dichloride 67.5%, methyl bromide 10%). Excellent results were obtained with carbon disulphide, but in the case of the bin fumigated with Dowfume Br 10, check capsules placed at various levels in the grain mass showed that the fumigant penetrated in lethal concentrations only to a depth of 8 feet below the surface.

Retention of Fumigant in a Sealed Bin

One of the bins at Hutchinson is constructed of steel plates bolted together in such a manner as to be tight enough to hold gasoline. The roof openings are sealed with rubber gaskets, so that this bin is as nearly gas tight as is possible short of welding the joints. This bin contains 4500 bushels of wheat and was fumigated with Dowfume Br 10 and sealed on November 18, 1941. On February 17, 1942, a probe containing live insects in check capsules at 2 feet intervals was inserted into the grain to a depth of 10 feet and left for 75 hours. No appreciable kill occurred, indicating that lethal concentrations of gas do not persist over long periods even in very tight bins.

Sampling methods

It has been customary in the past to base estimates of insect infestation of wheat stored in steel bins upon a 1000-gram sample. For practical purposes this method no doubt is sufficiently reliable to establish commercial grades. However, in the present study it seemed desirable to determine the size of sample necessary to provide a reasonably accurate estimate of the insect population in a bin, inasmuch as an important objective in the work is to determine the effect of various bin construction features and management practices on insect populations.

From the results of the October sampling at Hutchinson it appeared that a 1000-gram sample was inadequate with regard to insect infestation. Under the previous method of sampling, a composite sample, aggregating 4 to 6 quarts of grain, has been taken from 10 places in the bin. This composite, or average sample as it is called, is then run through a gram divider and cut to two portions of 1 quart each (approximately 1000 grams). One quart is sent to Chicago for grading and the other quart is examined for insects. The remaining 2 to 4 quarts has been discarded. In order to test the adequacy of this method, it was decided to divide the entire average sample into quart portions and determine the insect infestation in each quart.

This procedure was followed at both Jamestown and Hutchinson during the January and February quarterly sampling and as a result infestation data was obtained on 596 quarts at Jamestown and 578 quarts at Hutchinson. The infestation was so light at Jamestown that, except in one instance, it made no grade difference which quart was selected in determining whether or not a bin should be graded "weevily". At Hutchinson, where a much heavier infestation existed, in 4 out of 5 cases it made no difference which quart was used in determining the "weevily" grade. Thus, out of 142 bins sampled, in 115 bins or 81 percent it made no difference, but in 27 or 19 percent of the bins, the "weevily" grade depended on which quart was selected. However, in the latter group, more than half of the sub-samples graded weevily, except in border line cases where a difference of 1 insect would change the grade. It would thus appear that the divider performs a fairly accurate job in dividing the sample into representative portions.

To test further the accuracy of the divider in splitting a 4-quart sample of wheat containing a known number of insects into representative parts, 20 bran bugs were introduced and the grain was then run through the divider and split into 4 1-quart portions (approximately 1000 grams each). Theoretically there should have been 5 bran bugs in each quart--just enough to grade "weevily".

Actually, the number of bran bugs in each quart varied from 3 to 7. In ten trials, 4 out of 5 samples had 5 or more insects, the same ratio as was observed in the regular bin sampling.

In order to determine the variation between average samples, it is planned to take a large number of average samples from a single infested bin. This work is still in progress and the results will be included in a later report.

Cost of storage of wheat.

Inasmuch as the investigations on wheat storage in steel bins have been in progress for less than a year, only a limited amount of data are available relative to the cost of storage under the various management practices or treatments. According to figures supplied by Dr. H. J. Barre, Bureau of Agricultural Chemistry and Engineering, the original cost of the bin installation at Jamestown, North Dakota and Hutchinson, Kansas, was approximately 12 cents per bushel of storage space. The initial cost, of course, will be reduced in proportion to the length of the safe storage period.

The comparative cost of the various treatments applied to date in wheat storage investigations are listed below:

Fumigation	$5.20	per	1000	bushels
Turning	2.50	"	"	"
Cotton batts plus oil spray	1.10	"	"	"
Cotton batts, plain	0.98	"	"	"
Oil spray	0.12	"	"	"

From the above it will be seen that fumigation appears to be the most expensive treatment, but it should be borne in mind that all of the other treatments listed are preventive rather than curative, and their merits in prolonging the safe storage period for wheat have not as yet been fully demonstrated. Careful records on the cost of the various management practices and treatments are being kept so that the most economical and safest method may be determined.

Effect of Grain Moisture on the Development of Stored Grain Insects*

In previous tests conducted to determine the effect of grain moisture on the development of stored grain insects, no effort was made to control the factor of temperature. On account of the bulkiness of the equipment used in these first tests it was not feasible to conduct the tests under constant temperature conditions. Although these tests were carried on at ordinary room temperatures, seasonal fluctuations in out door temperatures greatly influenced the results. This was brought out in two series of tests using the same moisture content grain but carried on during different seasons of the year. In the series conducted when the daily mean temperature was 75° F., reproduction of practically all species included in the tests took place in corn with a moisture content of 9.5% or above, while the test conducted when the daily mean temperature averaged 71° F., no reproduction occurred in corn with a 10% moisture content. It is evident therefore that in order to definitely establish the effect of grain moisture on the development of stored grain insects, the factor of temperature must also be taken into consideration. By using 500 cc erlenmeyer flasks and 200 grams of grain we were able to use temperature controlled incubators, and thereby maintain a constant temperature throughout the test.

In the tests herewith reported three such temperature controlled incubators were used, set to maintain constant temperatures of 65, 70, and 75° F. Wheat with a moisture content of 9, 10, and 11%, infested with six common grain infesting species of insects was used. One hundred individuals of each of the following insects, namely, the granary weevil, rice weevil, confused flour beetle, lesser grain borer, sawtoothed grain beetle, and the rust red flour beetle, and 20 individuals of *Cynaeus angustus* were used in each grain moisture and temperature variant. The rust red flour beetle was not included in the outset of these tests but was included after *Cynaeus angustus* adults had all succumbed. Tables 6, 7, and 8 show the percentages of survival of these insects over a period of nine weeks. In general insofar as the percentage of survival is concerned the results are similar to tests run previously at room temperature. That is, the percentage of survival increases as the moisture content of the grain is increased irrespective of the temperature. Variations in the percentage of survival due to differences in temperature are, at this point in the tests, insignificant.

No reproduction has taken place in any of the lots to date. With three of the species, namely, the granary and rice weevils and the lesser grain borer, it is impossible to determine whether reproduction has occurred until adult progeny appear, since the immature stages feed within the wheat berry. In the case of the other four species, reproduction can be observed as soon as the eggs hatch, since the larvae feed externally on the grain or chaff and ground flour milled by the adults.

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* Reported by R. T. Cotton and J. C. Frankenfeld.

Table 6: -- Showing the percentage of survival of various species of stored grain insects when reared in 9, 10, and 11% moisture corn at 65° F.

Species of Insect	Percentage of survival after: 1 Week	3 Weeks	5 Weeks	7 weeks	9 Weeks
9% corn					
Granary weevil	92	80	70	57	54
Rice weevil	39	31	23	11	8
Confused flour beetle	99	99	99	88	76
Lesser grain borer	96	74	61	53	46
Sawtoothed grain beetle	100	100	97	94	87
Cynaeus angustus	80	0	0	0	0
Rust red flour beetle	94	66			
10% corn					
Granary weevil	95	90	90	81	77
Rice weevil	60	45	32	12	10
Confused flour beetle	97	91	90	83	69
Lesser grain borer	91	74	54	48	44
Sawtoothed grain beetle	97	87	76	61	45
Cynaeus angustus	75	0	0	0	0
Rust red flour beetle	82	62			
11% corn					
Granary weevil	100	96	96	95	91
Rice weevil	81	75	61	37	34
Confused flour beetle	98	92	91	88	79
Lesser grain borer	41	20	10	8	8
Sawtoothed grain beetle	97	94	85	80	79
Cynaeus angustus	90	12	0	0	0
Rust red flour beetle	100	96			

Table 7: -- Showing the percentage of survival of various species of stored grain insects when reared in 9, 10, and 11% moisture corn at 70° F.

Species of Insect	Percentage of survival after: 1 Week	3 Weeks	5 Weeks	7 Weeks	9 Weeks
9% corn					
Granary weevil	90	81	81	75	71
Rice weevil	13	7	6	0	0
Confused flour beetle	100	92	87	76	54
Lesser grain borer	35	6	2	0	0
Sawtoothed grain beetle	97	92	85	77	60
Cynaeus angustus	100	0	0	0	0
Rust red flour beetle	100	97			
10% corn					
Granary weevil	92	91	88	85	80
Rice weevil	57	50	34	18	9
Confused flour beetle	95	91	84	83	80
Lesser grain borer	32	16	10	9	9
Sawtoothed grain beetle	93	77	69	55	43
Cynaeus angustus	40	0	0	0	0
Rust red flour beetle	100	87			
11% corn					
Granary weevil	96	92	92	91	91
Rice weevil	76	73	58	49	29
Confused flour beetle	97	96	96	94	92
Lesser grain borer	2	0	0	0	0
Sawtoothed grain beetle	94	86	76	71	65
Cynaeus angustus	70	5	0	0	0
Rust red flour beetle	97	96			

Table 8: -- Showing the percentage of survival of various species of stored grain insects when reared in 9, 10, and 11% moisture corn at 75° F.

Species of Insect	Percentage of survival after:				
	Week	Weeks	Weeks	Weeks	Weeks
9% corn					
Granary weevil	96	91	88	85	58
Rice weevil	66	44	21	8	1
Confused flour beetle	100	92	80	60	35
Lesser grain borer	82	10	1	0	0
Sawtoothed grain beetle	100	97	93	88	66
Cynaeus angustus	95	0	0	0	0
Rust red flour beetle	97	96			
10% corn					
Granary weevil	96	95	94	88	83
Rice weevil	73	49	33	16	0
Confused flour beetle	97	92	86	84	86
Lesser grain borer	68	8	3	0	0
Sawtoothed grain beetle	99	84	65	54	39
Cynaeus angustus	70	0	0	0	0
Rust red flour beetle	100	99			
11% corn					
Granary weevil	87	83	83	79	79
Rice weevil	79	71	53	35	21
Confused flour beetle	99	95	92	87	86
Lesser grain borer	2	0	0	0	0
Sawtoothed grain beetle	99	93	86	69	62
Cynaeus angustus	55	0	0	0	0
Rust red flour beetle	97	92			

Laboratory Tests of New Materials for Grain Fumigation*

Laboratory tests are being made of a number of new materials to test their possibilities as suitable substitutes for grain fumigants now in use. Notes on two such chemicals tested follow.

1, 3-Dioxolane

Tests with 1, 3-Dioxolane indicate that it is not likely to be useful as a grain fumigant since a dosage equivalent to $49\frac{1}{2}$ lbs. per 1,000 bushels of grain failed to give a complete kill of grain infesting insects, in 20-liter flasks filled with grain in a 24-hour exposure period.

N-butyl bromide

Laboratory tests with N-butyl bromide indicate that in admixture with carbon tetrachloride it is an effective fumigant for stored grain. Rice weevil adults were killed in 24 hours with a dosage of slightly more than 1 pound per 1,000 bushels of grain. In fumigation tests it was applied in admixture with carbon tetrachloride at the rate of 1 part of N-butyl bromide to 4 of carbon tetrachloride.

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* Reported by R. T. Cotton and H. D. Young.